Germination.—MÜLLER[16] has done a very important piece of work on the breaking of seed and fruit coats in germination. The work deals with four general topics: (1) source of energy for breaking the coats; (2) structural features aiding in freeing the embryo; (3) measurement of pressure exerted against the coats by the growing contents; and (4) pressure required for bursting the coats in germination.

1. The author finds four different types of seeds and fruits as to the source of the pressure for bursting the coats: (*a*) swelling of the seed or fruit contents resulting from water absorption (swelling endosperm of *Ipomaea* and others, swelling embryo of *Chenopodina maritima*); (*b*) growth of endosperm (*Pinus Pinea*, *Ricinus communis*, and several others); (*c*) growth of cotyledons (*Prunus persica* and several other species of *Prunus*, *Juglans regia*, *J. nigra*, *J. cinerea*, and *Corylus avellana*); (*d*) growth of primary root or hypocotyl. In type (*d*) the author recognizes five different groups: (1) radicle borne between the subtending ends of the cotyledons and exerting its pressure upon the coat through these; (2) embryo located centrally in the endosperm and exerting its pressure upon the coat through this tissue (*Rumex* species, *Ruta graveolens*, *Nigella damascena*, *Viola tricolor*, etc.); (3) no nutrient tissue, embryo directly against the coat, hypocotyl in wedge-shaped cavity (*Helianthus annuus*, *Cucurbita Pepo*, etc.); (4) hypocotyl peripherally placed and in a wedge-shaped channel formed by integuments or by integuments and endosperm or cotyledons (*Ervum lens*, *Phaseolus multiflorus*, *Saponaria vaccaria*, *Potomogeton* species, etc.); (5) root or root-bearing portion of cotyledon generally cylindrical, pushing out through hole stopped by plug, lid, or valves (mostly monocots, as Marantaceae, Musaceae, Cannaceae, Phoenicaceae, etc.).

2. Under structural features of fruit or seed coats related to freeing of the embryo, the author discusses five classes: (*a*) free openings through which embryo grows without resistance (*Coix lacrymae*); (*b*) a special hole for exit of the embryo, the hole being stopped by a plug, cap, or valves (*Canna*, *Tradescantia*, *Commelina*, *Sparganium*, etc.); (*c*) a preformed dehiscent line (*Prunus*, *Pinus*, *Juglans*, *Amygdalus*, etc.); (*d*) zones of slight resistance at which coats break (Polygonaceae, some Lepidocaryeae); (*e*) no special mechanism (*Trigonella foenum graecum*, *Ligustrum vulgare*, *Capsicum annuum*, *Allium* species).

3. The pressure exerted against the coats by growing contents were measured for three forms. The growing cotyledon of *Corylus avellana* develops an average maximal outer pressure on the coat of 4759.42 gm., 34.14 gm. per mm.², or 3.305 atmospheres. The growing endosperms of *Ricinus communis* and *Pinus Pinea* develop a maximal average pressure of 4539.07 gm.

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[16] MÜLLER, GOTTFRIED, Beiträge zur Keimungsphysiologieuntersuchungen über die Sprengung der Samen- und Fruchthullen bei der Keimung. Jahrb. Wiss. Bot. 54:529–644. 1915.

and 4106.96 gm., 32.06 and 38 gm. per mm.², or 3,104 and 3.678 atmospheres respectively.

4. The hard seed and fruit coats of *Corylus* and *Pinus* are greatly weakened at the dehiscent line merely by water absorption. The breaking resistance offered by the soaked coats in these forms is generally one-half to one-sixth that offered by the dry coat. This weakening is not due to the dissolution of materials from the dehiscent line, for the old breaking strength is recovered upon drying. Soil agencies (bacterial, fungal, and acid effects) and enzymes from the living contents play no part in the dehiscence except where cellulose is present, as in *Juglans*. In *Pinus*, if rings of the coat were buried in soil for a period considerably exceeding germination time, the dehiscent zone was considerably weakened by soil agents. In these experiments, however, the agents can attack the dehiscent zone from every side. Water absorption also greatly lowers the breaking strength of brittle coats like *Ricinus*, as well as leathery or skinlike coats, as in *Vicia Faba*. It seems that the breaking strength of a great number of organic substances (*Laminaria* thallus, filter and parchment paper, etc.) falls greatly with water absorption and rises with water loss.

One must doubt the correctness of a fundamental assumption of MÜLLER in determining whether rupture of the coat is due merely to swelling or mainly to growth of the contents. If the bursting occurs at 0° C., MÜLLER pronounces it due to swelling; if only at a considerably higher temperature, to growth. The coats to be broken are gels of various consistency, which vary in viscosity and other physical characters, including no doubt breaking strength, with temperature, H+, OH−, and salt content. Again, the actual force with which the colloidal contents absorb water varies with conditions. We have found[17] cases where the coats are broken by swelling of the embryo and endosperm, but it occurs only at 15° C. or above, unless the coat is weakened by various treatments, when it occurs at 0° C. It is likely that there are cases where the seed or fruit contents exert much greater pressure upon the coats than those reported by MÜLLER (3–4 atmospheres). Indeed, CROCKER and DAVIS[18] showed by a very different method that the swelling embryo of *Alisma Plantago* exerts a pressure of about 100 atmospheres against the coat. Soil and other natural and applied agents play a much greater part in lowering the breaking strength of seed or fruit coats (*Alisma, Sagittaria, Amaranthus*, etc.) than MÜLLER found for the seeds upon which he worked. It seems odd that MÜLLER uses the micellar theory in his explanation rather than applying the modern colloid conception. There is no doubt that this leads him to certain incorrect inferences, such as cited above. It is very doubtful whether any generalizations can be drawn from MÜLLER'S measurements, since they cover so few forms and in the main the same types of seeds and fruits. For this

[17] Unpublished work by DAVIS and CROCKER.

[18] BOT. GAZ. **58**:285–321. 1914.

reason his pioneer work should be followed by a similar study of a great variety of seeds and fruits.—WILLIAM CROCKER.

Light and growth.—VOGT[19] has shown that the effect of light upon the growth rate of the coleoptile of *Avena sativa* is very complex, in contrast to the older statement that light always inhibits growth. Temporary illumination of sufficient intensity is shortly followed by a considerable decrease, which in turn is immediately followed by a greater and longer enduring increase in growth rate. This increase is due to the action of light alone, and not to the combined action of light and darkness. The initial inhibitory effect of light on growth is not due to increased transpiration, as BLAAUW[20] suggests. In sufficient illumination the rate and total amount of growth of this organ is reduced. The greater amount of illumination causes a second inhibitory effect, which greatly exceeds the former acceleration, so that the total effect is a marked reduction in rate and amount of growth. This total effect of light was all that was definitely studied before JACOBI's[20] work in 1911. In this total effect, like amount of light gives like effect, even within wide variation of the intensity and duration factors. For a given reduction in growth, *light intensity×duration of illumination* is a constant. This is the quantity of stimulus law which has been shown to have rather general application in growth and movement stimuli in plants. It seems then that there are three effects of light: inhibition, followed by a greater acceleration upon temporary illumination, and a second inhibition largely determining the total effect in long or enduring illumination of sufficient strength. These results tally in general with those of BLAAUW on sporangiophores of *Phycomyces*, except that BLAAUW has not found important the initial inhibitory effect of light.

While all the work of JACOBI, BLAAUW, and VOGT will greatly modify the statements current in our texts, there is one set of experiments by VOGT which is especially interesting in this respect. When the organ was alternately illuminated (100 M.K. or less) and darkened in 15, 30, or 60-minute periods, the illuminated periods gave less growth only in the 30 and 60-minute periods, and not in the 15-minute periods. In the longer periods, VOGT has shown that the greater growth in darkness is due largely to the stimulation effect of the previous illumination, and the slower growth in light is not due in the main to inhibitory effect of light. This quite reverses the former interpretation given to such results.

Red light acts as very weak diffuse light. This tallies with the known existence in the red of photo-stimulation power. A sudden change of 10–12° C. in the temperature has effects very similar to temporary illumination. This leads VOGT to inquire whether the effect of temporary illumination is not due

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[19] VOGT, E., Über den Einfluss des Lichts auf das Wachstum der Koleoptile von *Avena sativa*. Zeitschr. Bot. **7**:193–270. 1915.

[20] BOT. GAZ. **59**:67–68. 1915.